International Journal of Civil Engineering (IJCE)
ISSN(P): 2278-9987; ISSN(E): 2278-9995
Vol. 3, Issue 2, Mar 2014, 15-24

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

CHEMICAL ANALYSIS OF WASTEWATER-CONTAMINATED GROUND SOIL IN ARAR, SAUDIA ARABIA

ALNOS A. E. HEGAZY

Department of Civil Engineering, Faculty of Engineering, Northern Border University, Arar, KSA

Department of Civil Engineering, Faculty of Engineering, Benha University, Al Qalyubiyah, Egypt

ABSTRACT

Wastewater-contaminated soil and groundwater is generally noticed in many residential and industrial districts in various countries in the world. In Arar’s city, underground permeable septic tanks have been used to collect domestic wastewater from about 90% of residential buildings. Wastewater, natural soil and polluted soil samples were taken from five districts. A series of chemical analysis was carried out for the obtained samples. Organic, chemical and elemental compositions of wastewater and soil samples were identified and analyzed. Results showed that wastewater contains many injurious organic and chemical compositions. Also, the results indicated the wastewater seepage into ground has negative effects on the chemical compositions of polluted soil and dangerous effects on groundwater. Alerting the key persons, engineers and others about the dangerous effects on environmental and general health must be known and announced.

KEYWORDS: Contamination, Ground Soil, Groundwater, Organic Matter, Wastewater

INTRODUCTION

Human waste is a major component of sewage, but it could be an important source as fertilizer. Domestic wastewater consists of human feces, urine and grey water. Human excreta (feces and urine) consist of about 83% organic matter, 29% carbon and 11% nitrogen of dry solids. Where, organic matter content is the highest (≈92% of dry solids) in feces and highest nitrogen content (≈16% of dry solids) in urine, Giri, et al. [1]. In most situation, the chemical analysis shows that domestic and industrial wastewater contains chemical components, dissolved salts, organic matter, oil, grease, detergents, complex of solids, many types of metals, …etc. Moreover, the nature, type, physical and chemical properties in addition to contaminates concentration of wastewater depend upon its source, [2-4]

The percolation of wastewater into ground soil causes serious of geotechnical problems for underground constructions and groundwater. Among these problems are related to the construction materials of structural elements and environmental state. The chemical constitutive of wastewater plays a destructive role for reinforced concrete, steel and other construction materials, also, for increasing the toxicity and dangerous chemicals in soil and ground water [5-7].

Soil contamination is defined as the presence of man-made chemicals or other alteration to the natural soil constituents. This type of contamination typically arises from the rupture of underground storage tanks, application of pesticides and herbicides, percolation of contaminated surface water to subsurface strata, leaching waters from wastes of landfills or direct discharge of industrial wastes to the soil. The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, herbicides, lead and other heavy metals. The occurrence of this phenomenon is correlated with the degree of industrialization and intensity of chemical usage [5 & 8].

Arar’s city is the main city of Northern Border Region (NBR) at the north part of the Kingdom of Saudi Arabia (KSA). Generally, Arar’s city contains about 20 residential districts, as shown in Figure 1 as basic map of Arar’s city [9]. The sewage network is constructed and used for about 7% of residential area around the city center. In the other side, underground permeable septic tanks are used to collect about 93% of domestic wastewater. Where, these septic tanks are used to discharge wastewater into the ground. Therefore, it was strongly required to study the effects of domestic wastewater seepage into the ground on ground soil and groundwater.

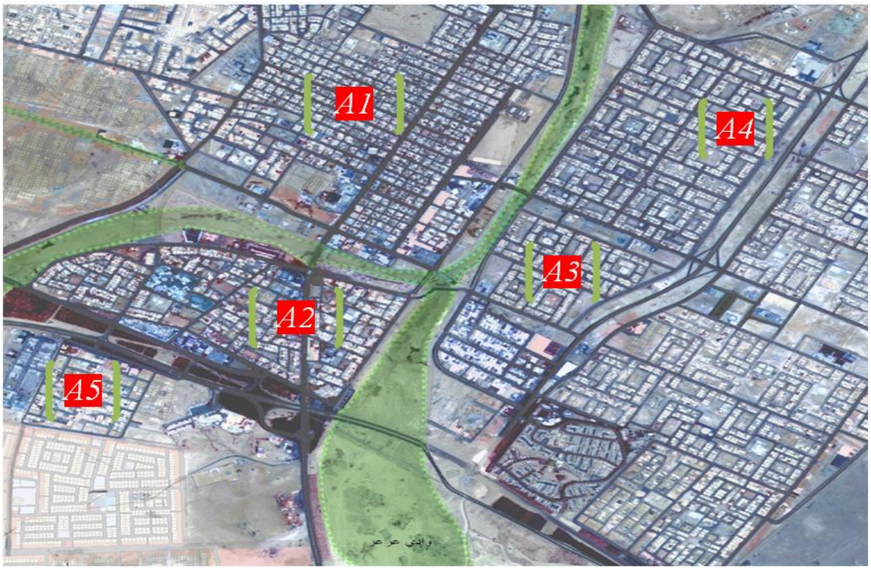


Figure 1: Basic Map of Arar’s City

THE STUDIED AREAS

Geo-graphical and topographical basic maps of Arar’s city were used to adapt the studied areas. Also, staff in Municipality of the Northern Border Region gives the complete knowledge about domestic wastewater collection and discharging. Generally, most buildings use permeable septic tanks for collecting domestic wastewater to discharge into ground. According to that, five areas were selected to study the influence of domestic wastewater on the chemical constituents of ground, as indicated in Figure 1.

The studied areas contain residual buildings of two to four stories. In addition to that, most of these buildings were constructed on the deposit soil of Wadi Arar. Where, soil deposit in Wadi Arar is physically formed and divided as transported soil and classified as silty Sand or gravelly silty Sand [10]. Square or rectangular underground permeable septic tanks have been used for collecting domestic wastewater and discharging into the ground. Most septic tanks have width more than 3.0 m and length than 4.0 m. While, its depth is about 3.0-4.5 m from ground surface, as a schematic plan and sectional elevation, Figure 2. Otherwise septic tanks are constructed by masonry or brick wall of 20-40 cm thickness which roofing by reinforced concrete (RC) slab, Figure 3(A). Additionally, septic tanks are constructed 3-10 m away from buildings with one tank for each building as shown in Figure 3(B). Also, it was found that wastewater inside septic tank was located at 1.50-2.00 m from the base level of tank, i.e. 2.50-1.50 m from ground surface, see Figure 2.

SAMPLING AND TESTING PROGRAM

An experimental program was prepared to investigate and study the effect of domestic wastewater seepage on the chemical constituents of ground soil and thus groundwater. At each of studied area, three samples of wastewater, natural

soil and contaminated soil were collected, see Figure 2. Where, wastewater samples were brought from septic tanks at about 25-40 cm below wastewater level in septic tank. In the other side, two natural soil samples were obtained from each studied area. First one (natural soil) was obtained from soil layer approximately at the same level of septic tank base. The second sample (polluted soil) was obtained from the depth of 20-25 cm below the septic tank base as shown in Figure 2. The following considerations were attended to obtain the samples of wastewater and soil:

- Wastewater samples were taken after sedimentation of solid particles at the quite side of septic tank.
- The first soil sample was obtained from more 15 m away from septic tank walls.
- Soil samples were obtained by using post-hole augers. While, wastewater samples were collected manually using plastic containers.
- Coding reference for obtained samples includes the area number and sample number was prepared. For example, soil sample A1-2 means that soil sample at the studied area1 (A1) and the soil sample 2. While, wastewater samples were coded as WW2 which represents wastewater samples from area2.
- For samples of wastewater and soils, field report contains in-situ visual inspection and GPS coordinates were prepared. Also, color and odor of each sample were inspected.

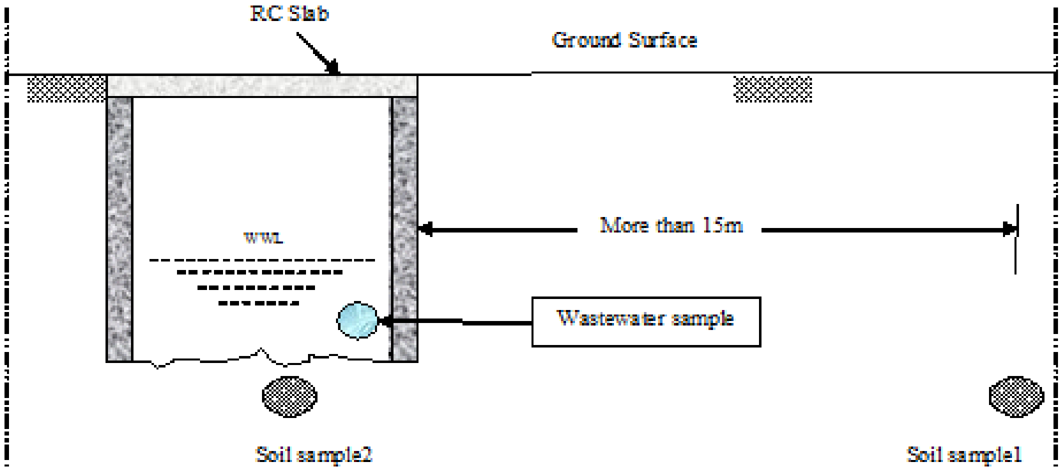
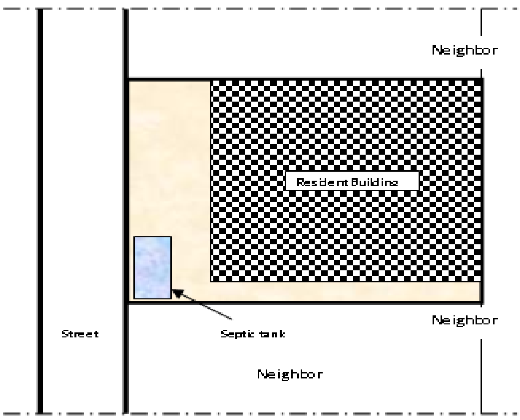


Figure 2: A Schematic Sectional Elevation for Obtaining Wastewater and Soil Samples



(A) Septic Tank Wall **(B) Layout of Septic Tank**

Figure 3: Septic Tank Walls and a Schematic Septic Tank Layout

Samples of wastewater were chemically analyzed to investigate physical properties, organic properties, chemical compounds, cations (metals) and anion group's compounds. The traditional manner of testing and the method of American Wastewater Analysis [11] were the guide of testing. Additionally, the tests of wastewater samples were carried out using: (a) BOD Analyzer Apparatus, (b) COD Analyzer Apparatus, (c) Atomic Absorption Spectrophotometer, AAS, and (d) UV- Visible Spectrophotometer. On the other side, traditional tests carried out on soil sample to determine pH, organic matter, sulphates, chlorides, cations and anion group's compounds,.....etc. The tests and result analyses were identified due to vogal [12]. Also, quantitative determination of the oxides Si, O_2, Al_2 O_3, Fe_2O_3 and others were carried out using X- ray fluorescence spectroscopy (Philips PW 1410). The structural formula and the cation exchange capacity were deduced, according to the method proposed by Nodeau and Bain [13].

WASTEWATER RESULT ANALYSIS

Physical properties of the wastewater are recorded in Table 1. Where, wastewater color is gray to dark gray and its medium is alkaline and approximately similar portable water as the values of pH.

Table 1: Average Physical Properties of Studied Wastewater

Property	Quantity				
	Area 1	Area 2	Area 3	Area 4	Area 5
Color	**Gray to Dark Gray**				
Temperature	26^{o}C	23^{o}C	25^{o}C	22^{o}C	24^{o}C
pH	7.6	7.4	8.1	7.5	7.8
Total Suspended Solids, TSS, (mg/l)	**423**	**561**	**487**	**398**	**504**

Otherwise, Table 2 contains the average measured values of studied wastewater organic properties. It is clear that the average values of VSS, BOD, TOD and COD are about 694, 404, 342 and 855 mg/liter respectively. Where, these results agree and reasonable with standard properties of wastewater as sewage network and treatment plants in KSA [15]. Also, the average values of oil &grease, phenol and detergents are 73, 4.25 and 12.8 mg/l respectively are approaching maximum standard values of pollution [14].

Table 2: Organic Properties of Studied Wastewater

Property	Quantity (Mg/Liter)				
	Area 1	Area 2	Area 3	Area 4	Area 5
Volatile Suspended Solids (VSS)	705	648	722	710	683
Biological Oxygen Demand (BOD)	386	412	408	395	421
Total organic carbon (TOD)	286	348	377	362	339
Chemical Oxygen Demand (COD)	813	876	881	846	857
Oil &Grease	74	66	65	82	78
Phenol	4.5	3.7	4.2	4.3	4.5
Detergents	12.5	14.4	14.7	10.8	11.7
Pesticides	--	--	--	--	--

Referring the chemical analysis results, as indicated in Table 3, the average values of chemical compounds of wastewater are about 737, 651, 167, 66 and 11 mg/l for Chlorides, Sulfate, Alkalinity, Ammonia and Phosphate respectively which are reasonable values comparing with maximum standard of wastewater pollution [14]. In addition to that, Table 4 illustrates the values of cations and anion groups of studied wastewater. It can be seen that some of cation and anion group's compounds are more than that mentioned as maximum polluted levels of wastewater [14] such as Cyanide and Copper, while, other values are reasonable such as Manganese and Chromium.

Table 3: Chemical Compounds of Studied Wastewater

Property	Quantity (Mg/Liter)				
	Area 1	Area 2	Area 3	Area 4	Area 5
Chlorides (Cl^-)	842	668	697	716	764
Sulfate (SO_4^{2-})	557	627	619	710	743
Alkalinity (as $CaCO_3$)	156	168	174	164	173
Ammonia (as NH_3-N)	68	62	57	74	67
Phosphate (PO_4^{3-})	11.5	13.7	9.5	8.9	11.2

Table 4: Cations (Metals) and Anion Group's Compounds of Studied Wastewater

Element	Quantity (Mg/Liter)				
	Area 1	Area 2	Area 3	Area 4	Area 5
Aluminum (Al^{3+})	0.25	0.20	.18	0.22	0.22
Chromium (Cr^{3+})	1.05	1.1	0.95	0.75	0.95
Copper (Cu^{2+})	1.0	1.3	1.5	2.0	1.4
Iron (Fe^{2+})	0.45	0.35	0.4	0.45	0.38
Lead (Pb^{2+})	1.1	1.05	0.90	1.05	0.85
Manganese (Mn^{2+})	3.5	4.2	4.1	3.7	3.6
Nickel (Ni^{2+})	1.85	1.70	1.55	1.65	1.90
Brone ($B^{3+)}$	1.76	1.82	1.76	1.54	1.80
Selenium (Se^{2-})	0.44	0.38	0.42	0.40	0.37
Fluoride (F^-)	6.9	8.8	7.5	8.0	7.6
Zinc (Zn^{2+})	3.00	2.70	2.25	1.85	2.60
Arsenic (As^{3+})	0.075	0.09	0.065	0.105	0.095
Cyanide (CN^-)	0.095	0.105	0.085	0.075	0.085
Mercury (Hg^{2+})	0.045	0.050	0.065	0.055	0.060
Cadmium (Cd^{2+})	0.03	0.025	0.015	0.025	0.025

SOIL CHEMICAL ANALYSIS RESULTS

The results of pH values for the tested soil samples are plotted as curves in Figure 4. These results indicated that the values of pH for polluted soils are high than that for natural soils. Where, the average value of pH for natural soil is about 7.42, while, the average value of pH for polluted soil is about 8.90. Referring to these results, it is obvious that the medium of polluted soil is increased in Alkalinity medium by about 20% than that of natural soil. Whereas, the pH values reflect the predominance of the nature salts, the discharging domestic wastewater into the ground has a bad effect on the engineering properties of ground soil and groundwater.

On the other side, the obtained results of organic matter content of studied soils, Figure 5, show that the values of organic matter content for polluted soils are extremely high than that for natural soils. Where, the average value of organic content for natural soil is about 0.76%, while, the average value of that organic for polluted soil is about 4.95%. Thus, the increase of organic matter content in polluted soils is about 650% than that of natural soils. It is generally known, that the organic matter content reflects the bad behavior of underlying soil. So, thus the discharging wastewater into the ground has a dangerous effect on the engineering properties of underlying soil.

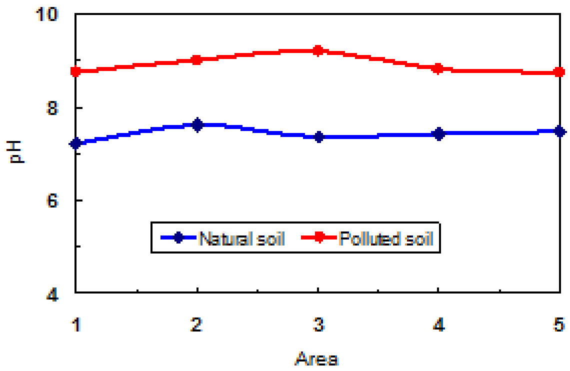


Figure 4: Ph Curves for Studied Soils

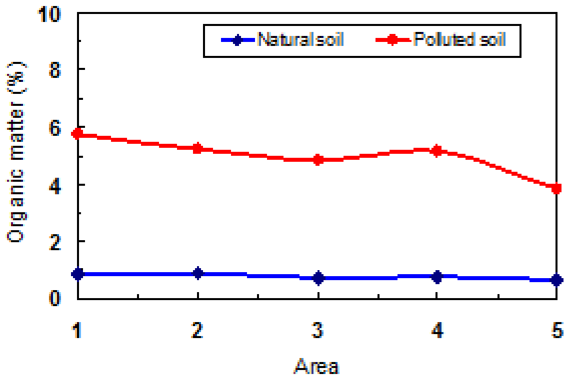


Figure 5: Organic Matter Content of Studied Soils

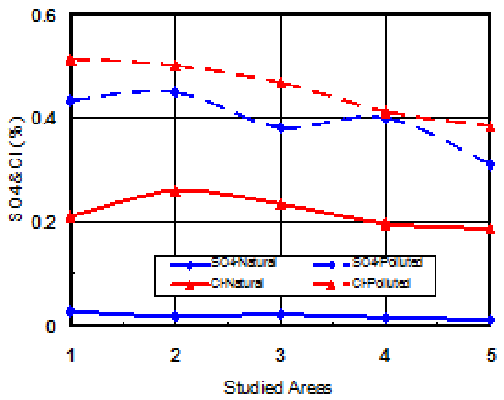
Otherwise, the average results of Sulphates (SO_4) and chlorides (CI) percent of studied soils are represented in Figure 6. By using the obtained data plotted in Figure 6, it can be seen that the sulphates (SO_4) and Chlorides (CI) contents for the wastewater-polluted soils are extremely increased than that for natural soils. Where, the average percents of SO_4 and Cl for polluted soils are 0.396 and 0.456, while, the average percents for natural soil samples are 0.018 and 0.218 respectively. For more indication, the values of SO_4 and Cl are increased in polluted soils by about 2200%, 200% respectively than that in natural soil. These results ensure with precision that, the increase of chloride contents (CI) in ground soil significantly increasing organic matter and colloidal soil. These results are consistent with the results of organic matter content for polluted and natural soils.

Figure 7 summarizes the curves of average values of cation exchange capacity (CEC) of the studied soils. Referring to the investigated results of cation exchange capacity, it is evident that the values of CEC for polluted soil samples are higher than that for natural soil samples by about 75%. Where, the average value of CEC for natural soil is about 4.176 meq./100gm. While, the average value of that CEC for polluted soil is about 6.97 meq./100gm. Additionally, these results are associated with the increase of organic matter materials in the polluted soil samples. It is known that CEC values depend upon the fine grains content and colloidal particles content in soils. Therefore, the high content of fine and colloidal particles in soil gives the high value of cation exchange capacity.

Elemental compositions as oxides of Si, Fe, Mg,...etc for studied soils are represented as curves in Figure 8 (A & B). Where, these values reflect the different forms of each individual element including soluble exchangeable and structural forms of ground soil. By analyzing these results, a number of useful facts can be noted as the followings according to the effect of wastewater on the elemental compositions of soils:

- Silicon oxide (SiO_2), Magnesium Oxide (MgO), Titanium Oxide (TiO_2), Potassium Oxide (K_2O) and Phosphorus Oxide (P_2O_3) percentage of polluted soil decrease by about 16%, 28%, 12.5%, 11% and 22% than that of natural soil. While, others such as Alumina Oxide (Al_2O_3), Iron Oxide or Ferric Oxide (Fe_2O_3), Calcium Oxide (CaO) and Sodium Oxide (Na_2O) percentage of polluted soil increase by about 10%, 18%, 18.5% and 32% than that of natural soils.
- The ignition loss or loss of ignition (L.O.I) percent of polluted soils increases than that of natural soil by values ranges about 30% and 107% according to the elemental composition of soil and changeable of their contents. Also, the increase of L.O.I. is derived with the increase of organic matter content and other soil chemical properties.

- Mostly, the increase or decrease of elemental compositions is associated with discharging wastewater into the ground soil. It can be concluded that the chemical constituents of wastewater may have significant effects on elemental compositions of ground soil and groundwater.



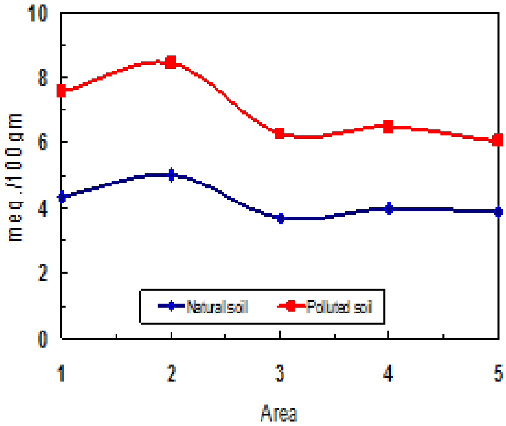
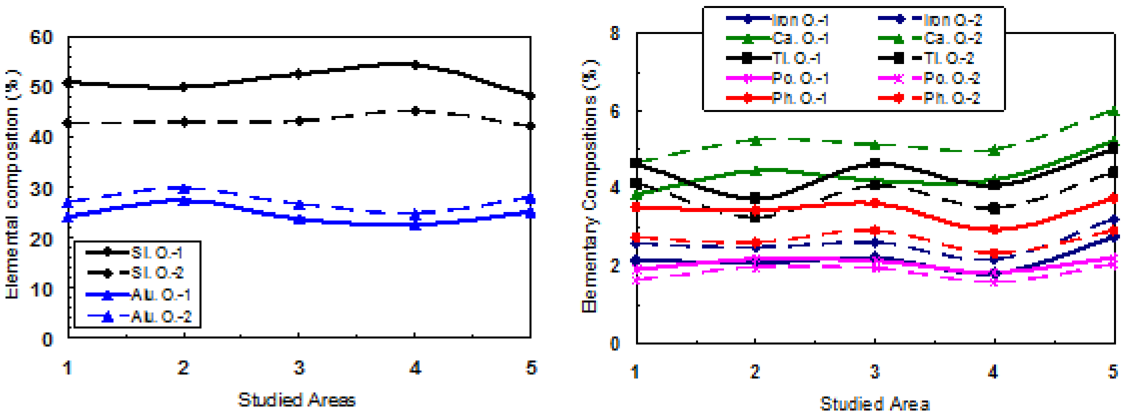


Figure 6: SO_4 and Cl Curves for Studied Soils

Figure 7: CEC Curves for Studied Soils



(A) SiO_2 and Al_2O_3 **(B) MgO, TiO_2, K_2O, P_2O_3 and Fe_2O_3**

Figure 8: Elemental Compositions Percentage for Studied Soils

DISCUSSIONS

In Arar's city, underground permeable septic tanks are used for collecting wastewater for discharging into the ground. The effects of wastewater constituents on chemical properties of ground soil and groundwater are investigated and discussed as the followings:

- In most situation, the chemical analysis shows that wastewater contains chemical components, dissolved salts, organic matter, oil and grease, complex of solids, many types of metals, …etc. Hence, the complex chemical processes between ground soil particles and wastewater chemical compositions are the main problems dealing with wastewater percolation to underlying soil.

- Wastewater contains heavy metals such as Cadmium, Lead, Zinc, Cyanide, Arsenic and Mercury…etc which are very dangerous for human, animals and plants. Where, these heavy metals are concentrated more than that recommended by the world standards for used water for drinking or irrigation.

- Chlorides and Sulfates concentration in the wastewater helps to increase their contents in ground soil and groundwater. Therefore, ground soil and groundwater properties are changed to the worst.

- Some heavy metals are relatively toxic to most plants and less to mammals as Copper (Cu^{2-}), Cadmium (Cd^{2+}) and Lead (Pb^{2+}) are toxicity chemical and cause anemia, high blood pressure, kidney diseases and kidney damage, also, destroys testicular tissue to aquatic biota as Hegazy and Abou-Rayan [6].
- With the increase of discharging wastewater into the ground, the concentration of inorganic elements is extremely increased in ground soil and groundwater. So, thus the ground soil and ground water become pollutant ccomponent.

Otherwise, The increase of Alkalinity medium by 20%, organic matter content by about 650%, sulphates (SO_4) content by about 2000% and Chlorides (Cl) content by about 200% of wastewater-contaminated soils than of natural soils reflects the followings:

- The predominance of the nature salts due to discharge domestic wastewater into the ground. Also, the dangerous effects of wastewater on chemical properties of ground soil.
- The effects of wastewater seepage on organic matter of soil and the spread of organic materials between soil grains. Additionally, the increase of organic matter in polluted soil reflects the bad behavior of underlying soil. These discussions agree with the study presented by Giri, et al. [1] and Hegazy and Hanamura [3].
- Cation exchange capacity (CEC) values for contaminated soil are associated with the increase of organic matter content, percentage of fine particles and colloidal fines.
- The chemical constituents of wastewater are transmitting to soil and spread between soil particles. Where, the increase of chloride contents (CI) in ground soils is connected with the increase of organic matter.
- Generally, the increase or decrease of elemental compositions is associated with seepage of wastewater into the ground soil and the occurred chemical processes. Additionally, the increase of L.O.I values is agreed with and depending upon the increase of organic matter and chemical compositions of polluted soil. These notes and discussions agree with the discussion mentioned by many researchers such as Giri, et al. [1], Zang et al. [5], Hegazy and Abou-Rayan [6].

CONCLUSIONS

Five districts of Arar's city are adopted for this study. Samples of wastewater, natural soil and contaminated soil were obtained for performing traditional and professional chemical tests. The results were recorded, analyzed, discussed and the following conclusions were obtained:

- With the discharging wastewater into the ground, many injurious chemical compositions in addition to toxicity and heavy metals are increased in groundwater and voids of ground soil. Also, wastewater specified as bad color and bad odor.
- Wastewater contains heavy metals which are very dangerous for human, animals and plants. Also, it contains organic chemicals which have bad effects on underground constructions and underlying soil.
- pH for contaminated soils are increased by about 20% than that for natural soil which increase of Alkalinity medium of contaminated soil.

- Organic matter, sulphates (SO_4) and Chlorides (Cl) contents of contaminated soils increase by about 650%, 2200% and 200% than that of natural soil respectively. These contents reflect the effects of wastewater seepage on organic materials of soil.
- Cation exchange capacity (CEC) for contaminated soil is higher than that for natural soil by about 75% associating with the increase of organic matter content.
- Some of elemental compositions contents are increased in contaminated soils and others are decreased by variant percent than that in natural soil.

To avoid the harmful effects of wastewater seepage into ground soils and groundwater, it is recommended: (a) the use of permeable underground septic tanks for collecting wastewater must be strongly prevented, (b) RC closed tanks must be used, (c) the complete sewerage networks must be constructed with good maintenance, and (b) Alerting key persons, designer, engineers and contractors on the dangerous future effects of wastewater on underground constructions, soils, groundwater, environmental and general health.

REFERENCES

1. Giri, R.R., Takeuchi, J. and Ozaki, H., “Influence of Night Soil Contamination on Activated Sludge Microbial Communities in Bangkok, Thailand”, Ecological Engineering, Vol. 25, pp. 395-404, (2005).
2. Yang, L., and Steefel, C.I., “Kaolinite Dissolution and Precipitation Kinetics at 22^{o}C and pH”Geochimica et Cosmochimica Acta72, online 23 Oct. pp. 99-116 www.sciencedirect.com, (2007).
3. Alnos Hegazy and Tetsuya Hanamura, 2009, “Physical Properties of Wastewater Contaminated Underlying Clayey Soil”, Journal of Environmental Science for Sustainable Society (JESSS), Japan, Vol. 3, pp. 9-18, (2009).
4. Holden W.R; Page, C.L. and Short, N.R., “The influence of Chlorides and Salphates on Durability", Corrosion of Reinforcement in Concrete Structures, Ellis Horwood Limited, London, (2008).
5. Zang, G.L., Yang, F.G., Zhao, Y.G., Zhao, W.J., Yang, J.L. and Gong, Z.T., “Historical Change of Heavy Metals in Urban Soils of Nanjing, China, During the Past 20 Centuries”, Environmental International, Vol. 31, No. 6, pp. 913-919, (2005).
6. lnos Hegazy and Ashraf Abou-Rayan, “Domestic Wastewater Effect on the Pollution of the Groundwater in Rural Areas in Egypt”, 14th International Water Technology Conference, IWTC 14, Cairo, Egypt, pp.909-923, (2010).
7. Negraa, Christine; S. Donald, Rossa and L. Antonio, “Oxidizing Behavior of Soil Manganese: Interactions among Abundance, Oxidation State and pH”, Soil Science Society of America Journal, Vol. 1, No. 69, pp. 97-111, 2006.
8. Baker, L.A., “Environmental Chemistry of Lakes and Reservoirs”, Advances in Chemistry Series 237, American Chemical Society, DC, (2009)
9. The Ministry of Municipal and Rural Affairs, Deputy Ministry for Urban Planning, 2012, “Public administration to coordinate projects”, KSA, (2012).

10. Mohamed A.M. Alghamdi and Alnos A. E. Hegazy, “Physical Properties of Soil Sediment in Wadi Arar, Kingdom of Saudi Arabia”, International Journal of Civil Engineering (IJCE) ISSN (P): 2278-9987; ISSN (E): 2278-9995, Vol. 2, Issue 5, pp. 1-8, (2013).
11. American Waste Water Analysis and Reuse, “Annual Book of Waste Water Standard”, Vol. 21-14, New York, (2004).
12. Vogle, J.M., "Quantitative Inorganic Analysis Including Elementary Instrumental Analysis”. Longman Group limited, Book Company, London, (2004).
13. Nodeau, J.M., and Bain, S.M., 1986, "X-Ray Fluorescence Identification and chemical Composition of Clays and Clay Minerals", Academic Press, London and New York.
14. The Ministry of Electricity and Water, Kingdom of Saudia Arabia (KSA), (2013),

http://www.cnbcarabia.com/?p=109877